Toward Cortically Inspired Learning in Fully Integrated OECT based Spiking Neural Networks

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Neuromorphic electronics aims to emulate the functionality of biological neural systems, offering a promising route toward highly energy-efficient information processing. Among neuromorphic approaches, spiking neural networks (SNNs) are particularly attractive due to their event-driven operation based on sparse electrical signals known as spikes, enabling low-power inference. However, training SNNs directly in hardware remains a major challenge and often relies on transferring pre-trained weights from conventional artificial neural networks. Developing hardware-native and biologically plausible learning mechanisms is therefore an important step toward autonomous neuromorphic systems, particularly for fully organic implementations targeting bioelectronic applications.

In this work, we outline a biologically inspired learning approach using previously reported SOMA neurons based on organic electrochemical transistors (OECTs) for fully integrated organic SNNs.[1] Inspired by biological pyramidal neurons, which are believed to separately process feedforward and feedback signals during inference and learning, respectively,[2] we propose using the two input terminals of our neuron circuit in an analogous manner. When a feedback signal from a teacher is applied to the secondary input following feedforward stimulation, the neuron generates an additional burst of spikes. This feedback-driven bursting behavior resembles burst-based learning mechanisms proposed for biologically plausible credit assignment in hierarchical neural networks.[3,4] Owing to the intrinsic short-term memory arising from OECT transient dynamics, we experimentally demonstrate that the strength of the teacher-induced burst depends on the temporal delay between the feedforward input and the feedback signal. This timing-dependent burst modulation may provide a mechanism for linking local plasticity rules with global error-driven adaptation in small fully organic neuromorphic networks, particularly for low-power edge bioelectronics applications.

[1] N. Prudnikov et al., 2026, arXiv, arXiv.2603.20954, 2026.

[2] M. Siegel et al., J Comput Neurosci, 8(2), 161-173, 2000.

[3] A. Payeur et al., Nat Neurosci, 24(7), 1010-1019, 2021.

[4] M. Stuck et al., Neuromorph. Comput. Eng., 5(1), 014010, 2025